MODIS LEVEL 1B 500M EARTH VIEW DATA PRODUCT FORMAT
Version 2.0 Release 1
March 19, 1997

If a packet hits a pocket on a MODIS product port
And the process is interrupted as a very last resort,
And the address of the memory tells the process to abort,
Then the packet pocket product has an error to report!

With apologies to "If Dr. Seuss Were a Technical Writer"....
J. Blanchette

Purpose

This document specifies the format and content of the MODIS Level 1B 500 meter Earth View data product, one of the four files designated as MOD02. MOD02 is stored as four Hierarchical Data Format (HDF) files for each granule of MODIS data, containing:

- Earth View observations for MODIS bands 1 and 2, at 250 meter resolution;
- Earth View observations from MODIS bands 1 and 2, aggregated at 500 meter resolution, plus the Earth View observations from MODIS bands 3 through 7, at 500 meter resolution;
- Earth View observations from MODIS bands 1 through 7, aggregated at 1 kilometer resolution, plus the Earth View observations from MODIS bands 8 through 36, at 1 kilometer resolution;
- On Board Calibrator observations from all MODIS bands, at their original resolution, plus the Engineering data.

This specification describes five types of metadata and two types of science data stored in the Level 1B 500M Earth View data product.

The indexing is described in terms of C, which is row dominant.

Metadata

The five types of metadata are Core, Archive, Product, Swath, and SDS. The Core, Archive and Product metadata are stored as global attributes. The Swath metadata is stored in two forms, as swath attributes for HDF-EOS required swath metadata, and as Vdata for Level 1B specific swath metadata. The SDS metadata is stored as Science Data Set (SDS) attributes.

The ECS required metadata in this file is written with the Science Data Processing Tool Kit (SDPTK) tools, so that it may be read with these tools.

Core metadata satisfies the ECS requirements to provide granule level information for ingesting, cataloging, and searching data products. The content and format of the Core metadata is defined by ECS.

Archive metadata provides granule level information that is archived with the product, but which is not stored in the searchable ECS database.

Product metadata satisfies the MODIS mission's requirement to track MODIS specific data at the granule level. The granule level information is output as global metadata elements stored using the HDF Attribute, in accordance with ECS guidelines

Swath metadata provides HDF-EOS required fields, instrument information, the nadir frame number, the latitude and longitude of the nadir frame, processing information and quality information about a particular swath of MODIS data.

Science Data

The science data in this file is Instrument data stored as multiple SDSs in HDF-EOS Swath format, without imbedded geolocation data. Separation of the complete set of geolocation data from the swath was approved by ECS for the MODIS project as a means of reducing redundant storage of the geolocation data in every product.

The dimensions of the SDSs are defined using HDF dimension names. Attributes associated with an HDF dimension are inherited by any SDS using that dimension name. This technique is used to provide multiple SDSs which have a common dimension with information such as band names, units, and scale and offset values.

Instrument SDSs

The target in the file described by this specification is the Earth View (EV) scene. The instrument data for the four calibration targets viewed by MODIS are stored in the OBC/Engineering file. The data at each resolution, for the EV scene, is in an SDS, so that there are the following two instrument data SDSs:

reflected solar band calibrated data at 250 M resolution aggregated to 500 M,
reflected solar band calibrated data at 500 M resolution.

The data in the instrument SDSs are scaled integers. Meaningful geophysical products are derived from these integer data sets through use of scaling factors and offsets provided in the SDS dimension attributes.

When the MODIS instrument is commanded to operate in night mode, the data taken by the Reflective Solar Band detectors is not telemetered down from the spacecraft. The SDSs for Reflective Solar Band data exist for all granules, but contain no data when the instrument is operating in night mode for the entire granule. The SDSs for Reflective Solar Band data contain fill data at the beginning or end of the granule when the instrument operations switch between day mode and night mode within the granule.

Dimension names are stored as attributes of the swath in the HDF-EOS swath metadata. The numbers of the bands in each SDS, the units of the calibrated data, and the scale and offset values for converting the integers to calibrated geophysical parameters are provided as SDS dimension attributes. These attributes are described in terms of ncdump output, where x.f represents a float32 value.

There is one scale and offset pair which provides the corrected raw counts, DN*, and two pairs of scale and offset values which provide radiance or reflectance related values, for each band. The emissive bands are reported as radiance products only. After multiplying by the scale and adding the offset to the integer values to restore them to calibrated geophysical quantities, the corrected counts will be in units of counts, the radiances will be in units of $\text{Watts} / \text{m}^2 / \mu\text{m} / \text{steradian}$; the reflectance related values [(EV BRF) * (cosine of the Solar Zenith Angle)] will be in units of per steradian. Thus,
radiance (Watts / m^2 / µm / steradian)=radiance scale(band#) * unsigned integer values + radiance offset (band#). The band dependent scales and offsets are determined as

$$scale = 1.2\left[\frac{L_{MAX_{band}}}{2^{15}-1}\right], \quad \text{and} \quad offset = -0.2\left[\frac{L_{MAX_{band}}}{2^{15}-1}\right], \text{ where } LMAX_{band} \text{ is the}$$

maximum radiance value for a band, and is defined to be 80% of the possible range. In terms of the reflectance related product, the band dependent scales and offsets are

$$scale = 1.2\left[\frac{(\rho\cos\theta)_{MAX_{band}}}{2^{15}-1}\right], \quad offset = -0.2\left[\frac{(\rho\cos\theta)_{MAX_{band}}}{2^{15}-1}\right],$$

where $\left(\rho\cos\Theta_{MAX_{band}}\right) = \frac{\pi}{E_{SUN_{nd}}} L_{MAX_{band}}$.

The relationship between reflectance (ρ_{EV}) and radiance (L_{EV}) is given by the equation $\rho_{EV}\cos\left(\Theta_{EV}\right) = \frac{\pi L_{EV,B,D}}{E_{Sun,B}}$, and is determined at the top of the

atmosphere. See the MODIS Level 1B Algorithm Theoretical Basis Document, 1996.

The numbers assigned by the hardware engineers to the detectors on the instrument are the reverse of the data storage numbering. The data in the Level 1A, Geolocation and Level 1B files is stored in the along-track direction. The nearest along-track data in a scan is collected by detector 20, for 500 meter bands, and the data farthest along-track is collected by detector 1. The pixel data within a band are stored this way so that consecutive swaths or scans can be "laid down" directly onto a map and have the correct continuity across each swath. All indexing and data ordering in this file are consistent, so that there is no need to explicitly transform between detector ordering and data ordering.

Invalid data fields are identified by having the high order bit set to 1. The data in a field is marked as invalid for the following reasons:

it was flagged as missing from the Level 1A dataset;
the detector is dead;
the value was saturated;
there was a calibration failure;
the radiance was too low to calculate;
there was coherent Space View (SV) noise;
the number of outliers in the SV data exceeded the maximum;
there was a mirror side difference in the SV data.

Thus any data value larger than 32767 should be interpreted as invalid data.

The values in data fields that are flagged as missing from the Level 1A dataset are copied into the Level 1B file exactly as they are stored in the Level 1A file. In the Level 1A file these values are -1, stored as signed 16 bit integers. In the Level 1B file these values are 65535, stored as unsigned 16 bit integers.

For invalid data that is not missing data, the actual value stored in the file is the value that is calculated by the algorithm, altered by having the high order bit set to 1.

The specific cause of all invalid data is reported in the QA log message file.

Other SDSs

Uncertainties SDSs

NOTE: At this point MCST is not yet certain that we have the optimum design for the Uncertainty Index and the Scene Contrast Index described in this section so that they are of optimal use to the science user. Any user who

plans to start using these indexes before the Version 2.1 release of the Level 1B software should contact MCST directly.

The product contains the flat-field uncertainty for MODIS, on a band averaged basis. The information is provided in two pieces: one piece is the instrument specification values; the second piece is the best estimate of what is actually accomplished, recorded as a multiplicative factor to be used with the instrument specification value.

The estimated uncertainty carried with each pixel is an eight bit field containing two indexes. The Scene Contrast Index is in the high order four bits and the Uncertainty Index described below is in the low order four bits.

The Scene Contrast Index includes near- and far-field effects. The concepts which describe the Scene Contrast Index are TBD at this time.

The Uncertainty Index is carried as a multiplicative factor to be applied to the instrument specifications. The instrument specifications are provided below, and may be stored in the Collect Level metadata, which is TBD. The uncertainty is recorded as an index which includes MCST's complete and best understanding of the flat-field uncertainties for that pixel. The index translates to an uncertainty value by use of the formula

$$\exp(\text{Uncertainty Index}/2) = \pm\text{Uncertainty Range Multiplier Value.}$$

The uncertainty is carried in the one-sigma sense. This index can be considered a Risk Index describing the use of the Level 1B data. An Uncertainty Index of 7 indicates that the uncertainty has not been computed.

As an example, for Band 9, one sigma is 5% of L_{typ}. Since L_{typ} = 41.9, one sigma = (.05)(41.9) = 2.095. If the uncertainty index has a value of 3, the magnitude of the uncertainty for Band 9 is $e^{3/2}$(2.095), or (4.5)(2.096) = 9.43.

Uncertainty Index Value	Multiplier Range (1 Sigma)
0	±1
1	±1.6
2	±2.7
3	±4.5
4	±7.4
5	±12
6	±20
7	greater than 20, index not computed

Band	Spectral Radiance Spec. (L_{typ})	Accuracy Requrement at L_{typ}	Band	Spectral Radiance Spec. (L_{typ})	Accuracy Requrement at L_{typ}
1	21.8	5%	18	3.6	5%
2	24.7	5%	19	15.0	5%
3	35.3	5%	20	0.45	0.75%
4	29.0	5%	21	2.38	1%
5	5.4	5%	22	0.67	1%
6	7.3	5%	23	0.79	1%
7	1.0	5%	24	0.17	1%
8	44.9	5%	25	0.59	1%
9	41.9	5%	26	6.00	5%
10	32.1	5%	27	1.16	1%
11	27.9	5%	28	2.18	1%
12	21.0	5%	29	9.58	1%
13lo	9.5	5%	30	3.69	1%
13hi	9.5	5%	31	9.55	0.50%
14lo	8.7	5%	32	8.94	0.50%
14hi	8.7	5%	33	4.52	1%
15	10.2	5%	34	3.76	1%
16	6.2	5%	35	3.11	1%
17	10.0	5%	36	2.08	1%

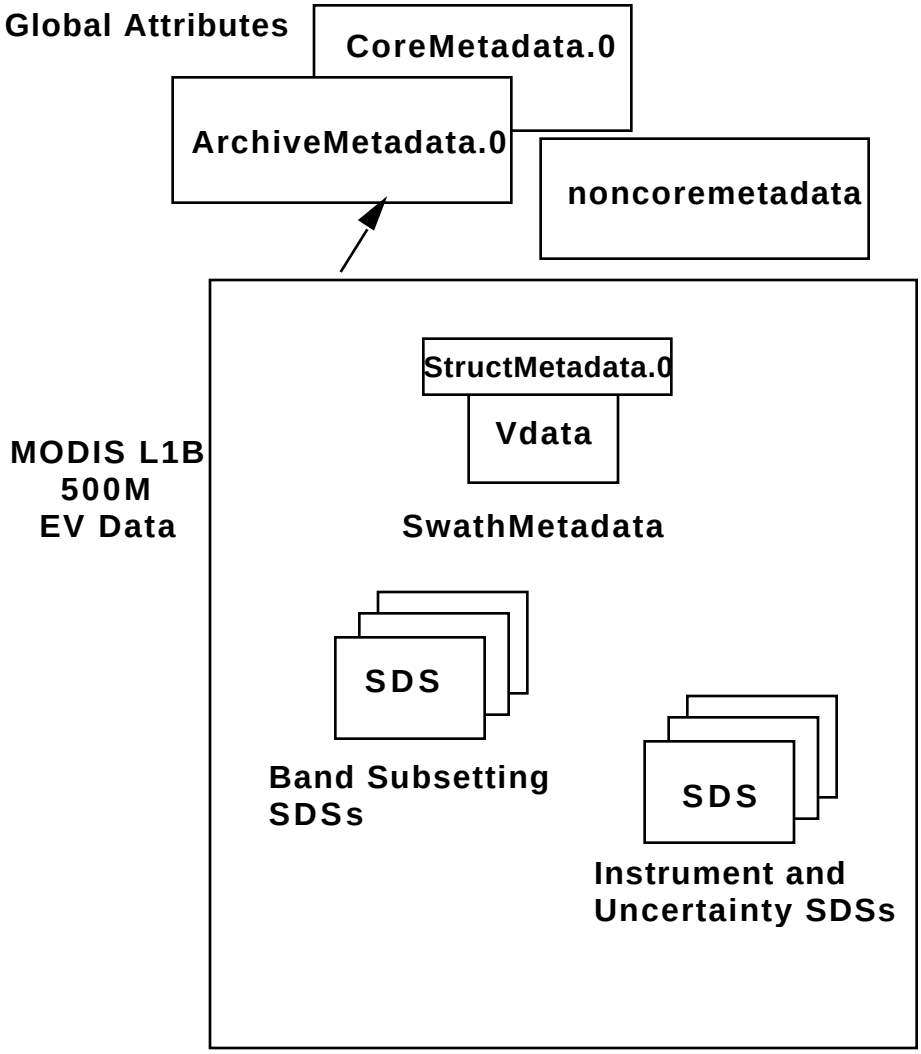
The center wavelengths for each band are given below. This information may also be stored in the Collect level metadata, which is TBD.

Band	Center Wavelength	Band	Center Wavelength	Band	Center Wavelength
1	645.0	13lo	667.0	23	4050.0
2	858.0	13hi	667.0	24	4470.0
3	469.0	14lo	678.0	25	4520.0

4	555.0	14hi	678.0	26	1375.0
5	1240.0	15	748.0	27	6720.0
6	1640.0	16	869.0	28	7330.0
7	2130.0	17	905.0	29	8550.0
8	412.0	18	936.0	30	9730.0
9	443.0	19	940.0	31	11030.0
10	488.0	20	3750.0	32	12020.0
11	531.0	21	3960.0	33	13340.0
12	551.0	22	3960.0	34	13640.0
				35	13940.0
				36	14240.0

Band Subsetting SDSs

The Band Subsetting SDSs support ECS subsetting of the band dimensions.



Level 1B HDF Format

Global Metadata

ECS Standard Core Granule Metadata **Stored as One ECS PVL String in :coremetadata.0=Global Attribute**	
Description	**Example**
SHORTNAME	"MOD02"
VERSIONID	"2.0"
SIZEMBECSDATAGRANULE	400. (Obtained from system at runtime)
EASTBOUNDINGCOORDINATE	40.000000
WESTBOUNDINGCOORDINATE	15.000000
NORTHBOUNDINGCOORDINATE	25.000000
SOUTHBOUNDINGCOORDINATE	10.000000
EXCLUSIONGRINGFLAG.1	"N"
GRINGPOINTLATITUDE.1	(25.000000, 20.000000, 10.000000, 15.000000)
GRINGPOINTLONGITUDE.1	(20.000000, 40.000000, 35.000000, 15.000000)
GRINGPOINTSEQUENCENO.1	(1, 2, 3, 4)
ORBITNUMBER	1234
RANGEBEGINNINGDATETIME	"2002-02-23T11:02:27.987654Z"
RANGEENDINGDATETIME	"2002-02-23T11:04:57.987654Z"
QAPERCENTINTERPOLATEDDATA	0
QAPERCENTOUTOFBOUNDSDATA	0
QAPERCENTMISSINGDATA	0
AUTOMATICQUALITYFLAG	"passed"
OPERATIONALQUALITYFLAG	"not being investigated"
SCIENCEQUALITYFLAG	"not being investigated"
QUALITYFLAGEXPLANATION	"not being investigated"
REPROCESSINGACTUAL	"processed once"
REPROCESSINGPLANNED	"no further update anticipated"
INPUTPOINTER	"L1A and Geolocation file name(s), Reflective.LUT, Emissive.LUT, sd.coeff.trend "
OPERATIONMODE	"day"

MODIS Level 1B Archive Granule Metadata Stored as HDF ECS PVL in :archivemetadata.0=Global Attribute	
Description	**Example**
PROCESSINGDATETIME	"2002-02-23T11:04:57.987654Z"
SPSOPARAMETERS	"The SPSO parameters (see database) for all data contained in this file"
ALGORITHMPACKAGEACCEPTANCEDATE	"1997-01-01"
ALGORITHMPACKAGEMATURITYCODE	"pre-launch"
ALGORITHMPACKAGENAME	"MOD02V2"
ALGORITHMPACKAGEVERSION	"version 2"
INSTRUMENTNAME	"Moderate-Resolution Imaging SpectroRadiometer"
PLATFORMSHORTNAME	"EOS AM1"
PROCESSINGCENTER	"GSFC"
ROUTINEINSTRUMENTOPERATIONS	“Y” or “N”
CALIBRATIONDATAQUALITY	“good”, “marginal” OR “bad”
NADIRPOINTING	“Y” or “N”
MISSIONPHASE	“A&E” OR “post A&E”

MODIS Level 1B Product Granule Metadata Stored as Native HDF Global Attributes		
Description	**Format**	**Example**
"Number of Scans"	Int32	203
"Number of Day mode scans"	Int32	203
"Number of Night mode scans"	Int32	0
"Incomplete Scans"	Int32	14
“Max Earth View Frames”	Int32	1354
"%Valid EV Observations"	float32[38]	98.2,..., 87.1,..,46.0,...
"%Saturated EV Observations"	float32[38]	1.4,..., 0.2,...,7.9,...
“Post Processing Indicates Bad data”	Int32[38]	1=True; 0=False
“Electronics Redundancy Vector”	uint32[2]	One bit set to 0 for Side A or 1 for Side B, for each programmable component
“Reflective LUT Last Change Date”	string	“1997-02-28T00:00:00”
“Emissive LUT Last Change Date”	string	“1997-02-28T00:00:00”
“Focal Plane Set Point State”	Int8[4]	0=Running open loop 1=Set Point is 83 degrees 2=Set Point is 85 degrees 3=Set Point is 88 degrees

Level 1B HDF-EOS Swath Metadata

Stored as HDF ECS PVL in :StructMetadata.0=Global Attribute
GROUP=SwathStructure GROUP=SWATH_1 SwathName="MODIS_Swath_Type_L1B" GROUP=Dimension Dimension_1, "Band_250M", Size=2 Dimension_2, "Band_500M", Size=5 Dimension_3, "10*nscans", Size=10*nscans Dimension_4, "20*nscans", Size=20*nscans Dimension_5, "Max_EV_frames", Size=Max_EV_frames Dimension_6, "2*Max_EV_frames", Size=2*Max_EV_frames GROUP=DimensionMap DimensionMap_1, GeoDimension="10*nscans", DataDimension="20*nscans", Offset=0, Increment=2 DimensionMap_2, GeoDimension=" Max_EV_frames", DataDimension=" 2*Max_EV_frames", Offset=0, Increment=2 GROUP=GeoField GeoField_1, "Latitude", DFNT_FLOAT32, ("10*nscans","Max_EV_frames") GeoField_2, "Longitude", DFNT_FLOAT32, ("10*nscans","Max_EV_frames") GROUP=DataField DataField_1, "EV_250_Aggr500_RefSB", DFNT_UINT16, ("Band-250M", "20*nscans", "2*Max_EV_frames") DataField_2, "EV_250M_Aggr500_RefSB_Uncert_Indexes", DFNT_UINT8, ("Band_250M", "20*nscans", "2*Max_EV_frames") DataField_3, "EV_500 _RefSB", DFNT_UINT16, ("Band_500M", "20*nscans", "2*Max_EV_frames") DataField_4, "EV_500M_RefSB_Uncert_Indexes", DFNT_UINT8, ("Band_500M", "20*nscans", "2*Max_EV_frames") DataField_5, "EV_250_Aggr500_RefSB_Samples_Used", DFNT_INT8, ("Band_250M", "20*nscans", "2*Max_EV_frames")

"**Level 1B Swath Metadata**" **Written as Vdata with the Following Fields**		
Field	**Type**	**Typical value**
Scan Number	int32	Range 1 to 100
Complete Scan Flag	int32	Complete=1, Incomplete=0
Scan Type	char8[4]	"D "=day, "N "=night, "M "=mixed, "O "=other
Mirror Side	int32	1 or 2
EV Sector Start Time	float64	TAI: Sec. since midnight 1/1/93
Programmed_EV_Frames	int32	1514
EV_Frames	int32	1354
Nadir_Frame_Number	int32	677

Latitude of Nadir Frame	float32	-90.0 to 90.0 in degrees
Longitude of Nadir Frame	float32	-180.0 to 180.0 in degrees
Solar Azimuth of Nadir Frame	float32	-180 to 180 degrees
Solar Zenith of Nadir Frame	float32	0.0 to 180.0 in degrees
No. thermistor outliers	int32	Range 0 to 12
Bit QA Flags	int32	1=True; 0=False
Moon in SV Port	bit 0	
Spacecraft Maneuver	bit 1	
Sector Rotation	bit 2	
Negative Radiance Beyond Noise Level	bit 3	
PC Ecal on	bit 4	
PV Ecal on	bit 5	
SD Door Open	bit 6	
SD Screen Down	bit 7	
SRCA On	bit 8	
SDSM On	bit 9	
Outgassing	bit 10	
Instrument Standby Mode	bit 11	
Linear Emissive Calibration	bit 12	
DC Restore Change	bit 13	
BB/Cavity Temperature Differential	bit 14	
BB Heater On	bit 15	
Missing Previous Granule	bit 16	
Missing Subsequent Granule	bit 17	
Remaining 14 bits reserved for future use	bits 18 - 31	

Band Subsetting SDSs		
SDS Name	**Data Type**	**HDF Dimension Names**
"Band_250M"	float32	floating point array of dimension (Band_250M)

Band_250M SDS Attributes: long_name ="250M Band Numbers for Subsetting" Note: The values stored in this array are 1.0 and 2.0 Band_250M Dimension Attributes: band_names = “1, 2” radiance_scales = x.f, x.f radiance_offsets = x.f, x.f radiance_units = “Watts / m^2 /µm / steradian” reflectance_scales = x.f, x.f reflectance_offsets = x.f, x.f reflectance_units = “1 / steradian” corrected_counts_scales = x.f, x.f corrected_counts_offsets = x.f, x.f corrected_counts_units = “counts”		
"Band_500M"	float32	floating point array of dimension (Band_250M)
Band_500M SDS Attributes: long_name ="500M Band Numbers for Subsetting" Note: The values stored in this array are 3.0, 4.0, 5.0, 6.0, and 7.0 Band_500M Dimension Attributes: band_names = “3, 4, 5, 6, 7” radiance_scales = x.f, x.f, x.f, x.f, x.f radiance_offsets = x.f, x.f, x.f, x.f, x.f radiance_units = “Watts / m^2 /µm / steradian” reflectance_scales = x.f, x.f, x.f, x.f, x.f reflectance_offsets = x.f, x.f, x.f, x.f, x.f reflectance_units = “1 / steradian” corrected_counts_scales = x.f, x.f, x.f, x.f, x.f corrected_counts_offsets = x.f, x.f, x.f, x.f, x.f corrected_counts_units = “counts”		

Instrument and Uncertainty SDSs		
"EV_250_Aggr500_RefSB"	uint16	16 bit scaled integer array of dimension (Band_250M, 20*nscans, 2*Max_EV_frames)

EV_250_Aggr500_RefSB SDS Attributes: long_name ="Earth View 250M Aggregate 500M Reflected Solar Bands Scaled Integers" Band_250M Dimension Attributes: band_names = “1, 2” radiance_scales = x.f, x.f radiance_offsets = x.f, x.f radiance_units = “Watts / m^2 /µm / steradian” reflectance_scales = x.f, x.f reflectance_offsets = x.f, x.f reflectance_units = “1 / steradian” corrected_counts_scales = x.f, x.f corrected_counts_offsets = x.f, x.f corrected_counts_units = “counts”		
"EV_250_Aggr500_RefSB_Uncert_Indexes"	uint8	8 bit integer array of dimension (Band_250M, 20*nscans, 2*Max_EV_frames)
EV_250_Aggr500_RefSB_Uncert_Indexes SDS Attributes: long_name ="Earth View 250M Aggregate 500M Reflected Solar Bands Uncertainty Indexes"		
"EV_250_Aggr500_RefSB_Samples_Used"	int8	(Band_250M, 20*nscans, 2*Max_EV_frames)
long_name = “Earth View 250M Aggregated 500M Reflected Solar Bands Number of Samples Used in Aggregation”		
"EV_500_RefSB"	uint16	16 bit scaled integer array of dimension (Band_500M, 20*nscans, 2*Max_EV_frames)
EV_500_RefSB SDS Attributes: long_name ="Earth View 500M Reflected Solar Bands Scaled Integers" Band_500M Dimension Attributes: band_names = “3, 4, 5, 6, 7” radiance_scales = x.f, x.f, x.f, x.f, x.f radiance_offsets = x.f, x.f, x.f, x.f, x.f radiance_units = “Watts / m^2 /µm / steradian” reflectance_scales = x.f, x.f, x.f, x.f, x.f reflectance_offsets = x.f, x.f, x.f, x.f, x.f reflectance_units = “1 / steradian” corrected_counts_scales = x.f, x.f, x.f, x.f, x.f corrected_counts_offsets = x.f, x.f, x.f, x.f, x.f corrected_counts_units = “counts”		
"EV_500_RefSB_Uncert_ Indexes"	uint8	8 bit integer array of dimension (Band_500M, 20*nscans, 2*Max_EV_frames)
EV_500_RefSB _Uncert_Indexes SDS Attributes: long_name ="Earth View 500M Reflected Solar Bands Uncertainty Indexes"		